CLAIMS

What is claimed is:

1. A wall shear stress sensor for measuring wall shear stress, the wall shear stress sensor comprising:

a sensor body;

an active sensing surface on the sensor body;

elastic means mounted between the active sensing surface member and the sensor body for allowing movement between the active sensing surface and the sensor body;

a driving means for forcing the active sensing surface to periodically oscillate or to perform non-periodic transient motion; and

a measuring means for measuring the position, and/or velocity, and/or acceleration of the active sensing surface relative to the sensor body, or to measure the time dependant force (or forces) between the oscillating active sensing surface member and the sensor body.

2. The wall shear stress sensor of claim 1 wherein the methodology of the active sensing device is applicable to active surfaces from sub-nanometer or single atom to tens of meters in size.

3. The wall shear stress sensor of claim 1 wherein the active sensing surface performs in a range of flows: (1) laminar and turbulent flows; (2) subsonic, transonic, supersonic and hypersonic flows; (3) incompressible and compressible flows; and (4) linear or non-linear rheology fluids.

4. The wall shear stress sensor of claim 1 wherein the motion of the sensing surface is selected from the group consisting of periodic, non-periodic, transient, translational and rotational, and result from the distortion of the body.

5. The wall shear stress sensor of claim 1 wherein the measuring means is selected from the group consisting of mechanical, electrical, magnetic, and radiative

6. The wall shear stress sensor of claim 5 wherein the measuring means is optical transduction.

7. The wall shear stress sensor of claim 6 wherein the optical transduction is selected from the group consisting of encoders, polarizers, moire patterns, interferometery, graded density filters, liquid crystals, apertures, reflective surfaces, and imaging.

8. The wall shear stress sensor of claim 1 wherein the measuring means is selected from the group consisting of analog, digital, continuous form, and discontinuous form.

9. The wall shear stress sensor of claim 1 wherein the driving means is selected from the group consisting of mechanical, electrical, magnetic, and optical.

10. The wall shear stress sensor of claim 9 wherein the mechanical driving means is selected from the group consisting of forces transmitted through solid members and machine elements selected from the group consisting of springs and forces transmitted through fluid media selected from the group consisting of hydraulic and acoustic forces.

11. The wall shear stress sensor of claim 10 wherein the forces result from a change in drag characteristics.

12. The wall shear stress sensor of claim 11 wherein the forcing waveform is selected from the group consisting of periodic and non-periodic.

13. The wall shear stress sensor of claim 11 wherein the forcing waveform is selected from the group consisting of be analog and digital.

14. The wall shear stress sensor of claim 11 wherein the forcing waveform is pulse width modulation.

15. The wall shear stress sensor of claim 1 and further comprising:
a forcing mechanism.

16. The wall shear stress sensor of claim 15 wherein the forcing mechanism is selected from the group consisting of fluid jet and inertial forces selected from the group consisting of an imbalanced rotor and an oscillating mass.

17. The wall shear stress sensor of claim 1 wherein the force given to the active sensor surface member is measured by directly measuring the force on the active sensor surface member by a transducer.

18. The wall shear stress sensor of claim 17 wherein the measuring of the force is selected from the group consisting of a load cell and by indirectly measuring the force on the active sensor surface member by measuring the input into the forcing means.

19. The wall shear stress sensor of claim 18 wherein the indirect measurement of the force is selected from the group consisting of voltage and current supplied to an electro-magnetic coil.

20. The wall shear stress sensor of claim 1 wherein the sensor is a mm scale devices fabricated from a material selected from the group consisting of metals, ceramic, glass, and or plastic.

21. The wall shear stress sensor of claim 1 wherein the sensor is a silicon based, micron scale micro-electro-mechanical device.

22. The wall shear stress sensor of claim 1 wherein the sensor is a nanometer scale nano-electro-mechanical device selected from the group consisting of carbon and inorganic nano-wire or nano-tube based.

23. The wall shear stress sensor of claim 1 wherein the driving means includes a driver mounted between the active sensing surface and the sensor body.

24. The wall shear stress sensor of claim 1 wherein the measuring means is a transducer mounted between the active sensing surface and the sensor body.

25. The wall shear stress sensor of claim 1 wherein the elastic means is selected from the group consisting of elastic and viscoelastic structural members.

26. The wall shear stress sensor of claim 1 wherein the elastic means includes suspension by a stationary or moving fluid or fluid filled chamber or chambers.

27. The wall shear stress sensor of claim 1 wherein the elastic means includes suspension selected from the group consisting of electric, magnetic, and gravitational forces.

28. The wall shear stress sensor of claim 1 wherein the elastic means comprises springs.

29. The wall shear stress sensor of claim 1 wherein the elastic means is selected from the group consisting of extensional and flexural structural elements.

30. The wall shear stress sensor of claim 28 wherein the springs are mounted between the active sensing surface member and the sensor body.

31. The wall shear stress sensor of claim 25 wherein at least one elastic leg or suspension element is mounted at any angle between the active sensing surface member and the sensor body.

32. A wall shear stress sensor for measuring wall shear stress, the wall shear stress sensor comprising:

an active sensing surface member;

an elastic or physical suspension for the active sensing surface member;

driving means for the active sensing surface member that produces periodic motion; and

measuring means for measuring the position, and/or velocity, and/or acceleration of the active sensing surface relative to the sensor body;

wherein, as the active sensing surface moves, time varying shear stress imposes a force with the magnitude of the shear force being different at different points and times within the periodic motion such that the variation of shear force within the motion results in a dampening of the motion of the active sensing surface member and a consequent change in the dynamics of the active sensing surface member.

33. A wall shear stress sensor for measuring wall shear stress, the wall shear stress sensor comprising:

an active sensing surface member;

an elastic physical suspension for the active sensing surface member;

driving means for the active sensing surface member that produces periodic motion; and

measuring means for measuring the position, and/or velocity, and/or acceleration of the active sensing surface relative to the sensor body;

wherein, as the active sensing surface moves, time varying shear stress imposes a force with the magnitude of the shear force being different at different points and times within the periodic motion such that the variation of shear force within the motion results in a dampening of the motion of the active sensing surface member and a consequent change in the motion of the sensor.

34. The wall shear stress sensor in claim 33 wherein the sensor is operated such that changes in the nature of the fluid properties or the fluid flow over the sensor change the amplitude and/or phase of the periodic motion of the active sensor surface.

35. The wall shear stress sensor in claim 33 wherein the periodic motion of the active sensing surface is selected from the group consisting of resonant, off-resonant, and non-resonant.

36. The wall shear stress sensor of claim 33 wherein an effectively frictionless measuring means continuously measures the position and/or velocity and/or acceleration of the oscillating active sensing surface member.

37. A wall shear stress sensor for measuring wall shear stress, the wall shear stress sensor comprising:

an active sensing surface member;

an elastic physical suspension for the active sensing surface member;

driving means for the active sensing surface member that produces periodic motion; and

measuring means for measuring the position, and/or velocity, and/or acceleration of the active sensing surface relative to the sensor body;

wherein, as the active sensing surface moves, time varying shear stress imposes a force with the magnitude of the shear force being different at different points and times within the periodic motion such that the variation of shear force within the motion results in a dampening of the motion of the active sensing surface member and a consequent change in the motion of the sensor.

38. The wall shear stress sensor of claim 37 wherein the wire has high tensile strength.

39. The wall shear stress sensor of claim 37 wherein the drive coil is a fixed frequency, electromagnetic drive coil.

40. The wall shear stress sensor of claim 37 wherein the drive coil drives the longitudinal motion of an oscillating active sensing surface plate near the resonant frequency.

41. The wall shear stress sensor of claim 37 wherein an effectively frictionless measuring means continuously measures the position and/or velocity and/or acceleration of the oscillating active sensing surface member.

42. The wall shear stress sensor of claim 37 wherein the oscillating plate vibrates at approximately twenty-seven (27 Hz) Hertz with longitudinal displacement amplitude of approximately three (3 mm) millimeters.

43. The wall shear stress sensor of claim 37 wherein the transducer is a linear Hall effect transducer continuously measuring the position of the oscillating active sensing surface plate.

44. A wall shear stress sensor for measuring wall shear stress, the wall shear stress sensor comprising:

an active sensing surface member;

an elastic or physical suspension for the active sensing surface member;

driving means for the active sensing surface member that produces periodic motion; and

measuring means for measuring the position, and/or velocity, and/or acceleration of the active sensing surface relative to the sensor body;

means for providing control feedback to the driving means such that it maintains a constant motion (amplitude and phase) of the active sensing surface;

means for measuring the time-dependent force or power provided by the driving means;

wherein, as the active sensing surface moves, time varying shear stress imposes a force with the magnitude of the shear force being different at different points and times within the periodic motion such that the variation of shear force within the motion results in a dampening of the motion of the active sensing surface member and the control system compensates for the presence of the additional damping by providing increased time dependant force or power or changing the phase relationship between forcing and motion so as to achieve approximate or exact specified motion.

45. The wall shear stress sensor of claim 44 wherein the sensor is operated with an analog control system such that the driving mechanism compensates for any change in time-dependant forces by changing the instantaneous force or power or changing the phase of the forcing to achieve approximate or exact specified periodic motion.

46. The wall shear stress sensor of claim 44 wherein the sensor is operated with a digital control system such that the driving mechanism compensates for any change in time-dependant forces by discontinuously changing the instantaneous force or power or changing the phase of the forcing to achieve approximate or exact specified periodic motion.

47. The wall shear stress sensor of claim 44 wherein the sensor is operated with a mixed analog-digital control system such that the driving mechanism compensates for any change in time-dependant forces by continuously or discontinuously changing the instantaneous force or power or changing the phase of the forcing to achieve approximate or exact specified periodic motion.

48. The wall shear stress sensor of claim 44 wherein an effectively frictionless measuring means continuously measures the position and/or velocity and/or acceleration of the oscillating active sensing surface member.

49. The wall shear stress sensor of claim 44 wherein a measure of the instantaneous force or power supplied by the driving means is related to the dampening.

50. The wall shear stress sensor of claim 44 wherein the forcing means is an electro-magnetic coil wherein a measure of the instantaneous voltage or current supplied to the driving means is related to the dampening.

51. The wall shear stress sensor of claim 44 wherein the force given to the active sensor surface member is measured by directly measuring the force on the active sensor surface member by a transducer including but not limited to a load cell, or by

indirectly measuring the force on the active sensor surface member by measuring the input into the forcing means.

52. The wall shear stress sensor of claim 51 wherein the force is measured by a method selected from the group consisting of voltage and current supplied to an electro-magnetic coil.

53. A wall shear stress sensor for measuring wall shear stress, the wall shear stress sensor comprising:

an active sensing surface member;

an elastic or physical suspension for the active sensing surface member;

driving means for the active sensing surface member that produces non-periodic motion; and

means for measuring the position, and/or velocity and/or acceleration of the active sensing surface member;

wherein, as the active sensing surface moves, time varying shear stress imposes a force with the magnitude of the shear force being different at different points and times within the motion such that the variation of shear force within the motion results in a dampening of the motion of the active sensing surface member.

54. The wall shear stress sensor of claim 53 wherein the variation of shear force within the motion results in a change in the transient motion of the active sensing surface member.

55. The wall shear stress sensor of claim 53 wherein the variation of shear force within the motion results in a change in the time-dependant forcing required to maintain a specified transient motion.

56. The wall shear stress sensor of claim 55 wherein a measure of the time dependant force or power supplied by the driving means is related to the dampening.

57. A method for measuring wall shear stress, the method comprising:

providing an active sensing surface;
elastically mounting the active sensing surface member;
forcing the active sensing surface to move; and
measuring or controlling the time-dependant position, and/or velocity and/or acceleration of the active sensing surface.

58. The method of claim 57 further comprising: providing periodic oscillatory motion to the active sensing surface member, such that the variation of shear force within the motion results in a positive or negative dampening of the motion of the of the active sensing surface member and a consequent change in the amplitude or phase characteristics of the periodic position, and/or velocity or and/or acceleration of the active sensing surface.

59. The method of claim 57 and further comprising:
providing periodic oscillatory motion and a control system such that the variation of shear force within the motion results in a positive or negative dampening of the motion of the of the active sensing surface member and a consequent change in the time dependant forcing required to maintain approximate or exact specified periodic active sensing surface position, and/or velocity or and/or acceleration waveforms.

60. The method of claim 57 and further comprising:
providing non-periodic transient motion to the active sensing surface member, such that the variation of shear force within the motion results in a positive or negative dampening of the motion of the of the active sensing surface member and a consequent change in the transient motion of the active sensing surface member.

61. The method of claim 57 and further comprising:
providing non-periodic transient motion and a control system such that the variation of shear force within the motion results in a positive or negative dampening of the motion of the of the active sensing surface

member and a consequent change in the time dependant forcing required to maintain approximate or exact specified transient active sensing surface member position, and/or velocity and/or acceleration profiles.

62. A method for measuring wall shear stress, the method comprising:
providing an active sensing surface that consists of a plate that oscillates parallel to the surface on which the sensor is to be installed;
elastically mounting the active sensing surface member;
forcing the active sensing surface to move periodically at or near resonance;
dampening of resonant forced vibration of the oscillating plate due to time varying shear forces resulting in changed oscillation magnitude or phase; and
measuring of the time-dependant position, and/or velocity and/or acceleration of the active sensing surface to determine the change in oscillation magnitude or phase.

63. A method for measuring wall shear stress, the method comprising:
providing an active sensing surface that consists of a plate that oscillates parallel to the surface on which the sensor is to be installed;
elastically mounting the active sensing surface member;
forcing the active sensing surface to move periodically at or near resonance;
dampening of resonant forced vibration of the oscillating plate due to time varying shear forces; and
measuring of the time-dependant or time-averaged force or power provided by the forcing means required to maintain approximate or exact specified periodic active sensing surface position, and/or velocity or and/or acceleration waveforms.